Roentgenographic Study of the Volume of the Sella Turcica
Part 3. Evaluation on the Estimating Method of the Volume

By

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トルコ鞍容積のX線学的研究 (第3報)
容積算定法

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著者はX線学的にトルコ鞍容積を算定する事を試み, $V = 2/3$ (L×D×W) という実験式を考え, その基礎となるX線解剖学及び計測点に関して報告してきた. 今回は屍体頭部12例, 乾燥頭蓋骨70例を使用してX線学的容積と解剖学的容積及び下垂体容積との相関を研究し, 諸家の算定法, 特に DiChiro 氏法と詳細に比較した.

著者の式によるX線学的容積と解剖学的容積との平均誤差は8%(0~20%), 相関係数+ 0.863, X線学的容積と下垂体容積との平均誤差は27% (7~58%), 相関係数+ 0.818であつた. これらの数字は諸家の算定式と比較して, 著者の算定式は劣るものでない事を証明している(第1, 2表). 最後に下垂体とトルコ鞍容積の相関に関して若干の文献考察を行つた (第3表).

In the preceeding papers, the author's roentgen anatomical background[30] and measuring points[31] of the sella turcica in the roentgen-volumetric study have been presented. In this series, the author has primarily took head on the following points; It should not be difficult to obtain the sellar volume for general clinicians in their busy practice. Special equipments and apparatus such as tomography and planimeter, are not necessary. Specific trainings are unnecessary. But, however, the results obtained must be accurate as possible as can be.

The author[29] proposed an experimental formula for estimation of the sellar volume, $V=2/3$ (L× D×W), where V is volume, L length, D depth, and W width. The purpose of this paper is to evaluate this formula in comparing the roentgenographic volume with the anatomical sellar volume and with the pituitary volume.

Evaluation of Author's Method

Object A. Relationship between the roentgenographic volume and the anatomical volume of the sella turcica

Material and Method

70 cases of dry skulls were used.

1) The roentgenograms of dry skulls were taken in the straight postero-anterior and lateral pro-

jections, and roentgenographic volume (Vr) was calculated.

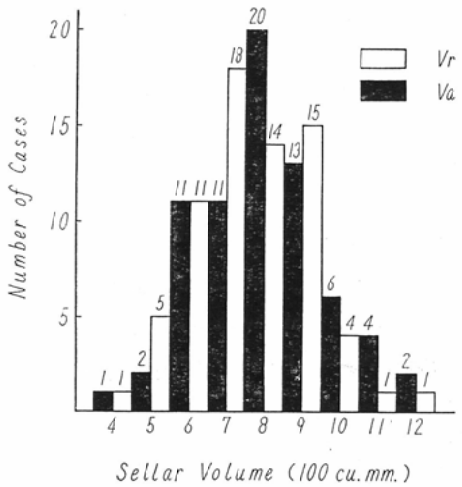
2) The sella turcica of the dry skull was filled with dental wax, which possess favorable qualities for the specific gravity (1.4), cohesiveness (solid) and malleability (soft) in accordance with temperature. The superior surface of the cast was taken to be the diaphragma sellae and the lateral margin was chosen as for the edge of the sellar floor. The wax was then taken out from the cast, and was weighed for the transference to the volume. Two or three molds were made from each of the dry skulls in order to minimize the errors as low as possible. The mean value was regarded as the anatomical volume of the sellar cast (Va).

3) The discrepancy between Vr and Va was calculated.

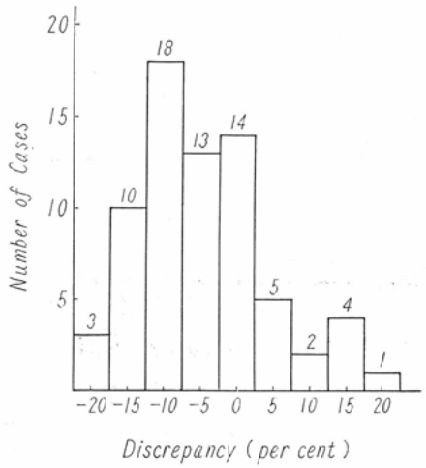
Result of object A.

The results of estimating the roentgenographic and anatomical volume of the sellar cast, and the discrepancy between them are shown in Table 1 and 2, and also diagrammatically in Graph 1, 2, and 3.

The roentgenographic volumes ranged from 450 to 1200 cu. mm., with an average of 808.5 cu. mm. (Graph 1). The cast volumes ranged from 478 to 1257 cu. mm., with an average of 852.8 cu. mm. (Graph 1). The discrepancy between them averaged 8.0 per cent of the cast volume, with a range of zero to 20 per cent (Graph 2). In 51 of 70 cases, the roentgenographic volumes were smaller than the cast volumes.



Graph 1. Frequency Distribution of Roentgenographic and Anatomical Volume of Sella Turcica in 70 Dry Skulls.



Graph 2. Frequency Distribution of Discrepancy between Roentgenographical and Anatomical Volume of Sella Turcica

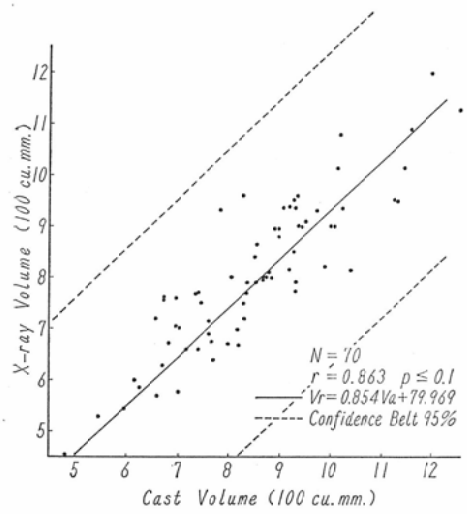
The correlation between Vr and Va was 0.863, a figure significant at the 1 per cent level. Graphic representation of this correlation with confidence belt, is presented in Graph 3.

Object B. Relationship between the roentgenographic volume of the sella turcica and the anatomical volume of the pituitary gland.

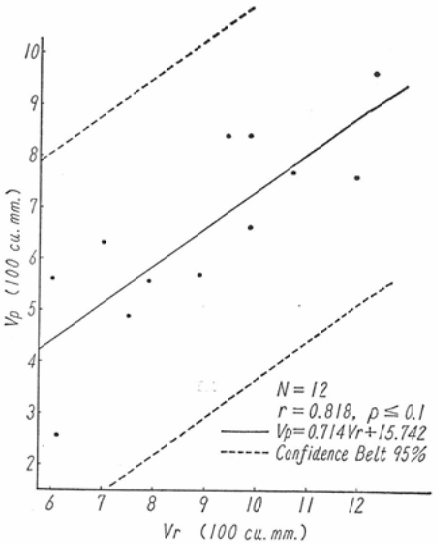
Material and Method

12 skulls of the fresh cadavers with removed brains were used.

1) The roentgenograms of all skulls were taken in the straight postero-anterior and lateral projections, and the roentgenographic volume was calculated.



Graph 3. Relationship between Roentgenographic and Anatomical Volume of Sella Turcica



Graph 4. Relationship between Roentgenographic Sellar Volume and Anatomical Pituitary Volume

2) The diaphragma was incised, and the pituitary gland was removed with the thin capsule. Removed pituitary gland was preserved in 10 per cent formalin, becuase the fixation in 10 per cent formalin did not produce any significant shrinkage[8]. The pituitary gland was, then, weighed and transfered to the volume (Vp).

3) The discrepancy between Vr and Vp was calculated.

Result of object B.

Approximate results of this study were already reported in the previous paper[29]. The author found the roentgenographic predictions of sellar volume to average 895.6 cu. mm., and range from 600 to 1232 cu. mm. (Table 1). The average pituitary gland volume was 655.2 cu. mm., with a range from 256 to 910 cu. mm. (Table 1 and 3). The data show that a correlation between Vr and Vp was 0.818, a figure

Table 1. Relationship between Vr, Va and Vp.

Author	Seki	Di Chiro-Nelson[6]
Measuring Points		
Formula	$V=\frac{2}{3}(L\times D\times W)$	$V=\frac{1}{2}(L\times H\times W)$
Relationship between Vr and Va		
Number of Cases	70	46
Vr : Mean (Range) (cu.mm)	808 (450–1200)	654 (450–1092)
Va : Mean (Range) (cu.mm)	853 (478–1257)	754 (489–1229)
Discrepancy : Mean (Range) (%)	8.0 (0 – 20)	16.9 (0 – 83)
Vr < Va (%)	72.9	82.6
Correlation Coefficient	0.863	0.719
Relationship between Vr and Vp		
Number of Cases	12	46
Vr : Mean (Range) (cu.mm)	896 (600–1232)	654 (450–1092)
Vp : Mean (Range) (cu.mm)	655 (256 – 910)	608 (400 – 945)
Discrepancy : Mean (Range) (%)	27 (7 – 58)	12 (1 – 103)
Vr > Vp (%)	100.0	77.8
Correlation Coefficient	0.818	0.720

significant at the 1 per cent level (Table 1 and 3). Graph 4 shows this correlation with confidence belt. The discrepancy between them in each case averaged 27 per cent of Vr, with a range of 7 to 58 per cent. In all of 12 cases, the roentgenographic volume was larger than that of the pituitary gland.

Discussion

When one tries to estimate the sellar volume, one must consider the shape of the sella turcica; whether cylindrical or ellipsoid. According to the consideration, it happens naturally that the estimtaing formula differs in accordance with shape. When the shape of the sella is cylindrical, the fundamental formula is Volume=Area×Width.[5)20)22)36)]

Meldolesi and Pansadoro[20)] were, perhaps, the earliest workers to calculate the volume of the sella turcica from roentgenograms (Table 2). They used the narrowest width of the dorsum sellae in the Chamberlein-Towne's view as for the sellar width.

Table 2. Roentgenographical and Anatomical Volume (cu. mm.) of Sella in Adults

	Cast			V=	Roentgenographic			N	Error
	N	M	Range		N	M	Range		
Meldolesi-Pansadoro[20)]	12	985	411—1314	Area × Dorsum	34	985	561—1410	12	10.4
Cardillo-Bossi[5)]	17	911	270—1216	(Area—5%) × (dorsum—10%)	15	960	345—1804	15	12.5
				(Area×5%) × (laminographic diameter of floor —11.5%)	17	889	263—1729	17	5.1
DiChiro-Nelson[8)]	48	754	489—1229	1/2 (L×H×W)	49	654	450—1092	46	16.9
Seki	70	835	478—1257	2/3 (L×D×W)	70	808	450—1200	70	8.0

Vallebona and Conte[35)] suggested using the area multiplied by the transverse diameter of the sella obtained by laminography, but presented no data to test their formulation.

Cardillo and Bossi[5)] tried to compare Meldolesi and Pansadoro's method (with their slight modefication) with their own proposed method, which was the multiplication of the area minus 5 per cent by the transverse diameter of the sellar floor minus 11.5 per cent revealed by laminography (Table 2).

DiChiro[7)] was perhaps, the first author, who tried to estimate the radiographic sellar volume from three linear components. For estimation of the sellar volume, he proposed a formula, considering the sellar shape as an ellipsoid: $V=1/2\ (L\times H\times W)$, where L is length, H height, and W width.

The author[29)], also, tried to calculate the volume from three linear components, though the shape of the sella was regarded as a cylindrical and the lateral profile as a part of an elliptic. The shape of the sella turcica is, of course, not exactly cylindrical, but barrellike. The author believes that consideration, which regards the sellar shape as an ellipsoid, is more suitable for the shape of the pituitary gland. As shown in Table 1, DiChiro-Nelson's data[8)] have verified this fact clearly with their wonderful success. In 46 cases of adults, their data have showed that an average discrepancy between Vr and Vp is 12 per cent and a correlation between them is 0.720. On the other hand, the discrepancy between Vr and Va shows an average of 16.9 per cent, with a range from zero to 83 per cent. The correlation between them is 0.719. On the contrary from the good results of the former, the data in the later are not so satisfactory. Although they stated the difficulty in the determination of the anatomical sellar volume, their high figures of the discrepancy and relative low correlation may be probably due to following factors: The

one is the difference in their measuring points, which they defined the greatest antero-posterior diameter in a horizontal plane for length (Table 1). Many workers have used this definition for length, but the author is of the opinion that this measuring point is ambiguous and inaccurate. Next is, as mentioned above, the difficulty in the determination of the anatomical sellar volume. This is surely the most probable factor, and their data show that the discrepancy between Va and Vp averaged 20 per cent, and that the correlation was 0.646, significant at the 1 per cent level. In addition to these factors, DiChiro's hypothesis[7] on the sellar shape seems to participate in the increase of the discrepancy and in the decrease of the correlation between Vr and Va, because the estimated volume based upon the formula for an ellipsoid is naturally smaller than the true volume.

Table 3. Anatomical Volume (cu. mm.) of Sella Turcica and Pituitary Gland in Normal Adults

Author	Year	No. of Cases	Sellar Volume		Pituitary Volume		Remarks
			Mean	Range	Mean	Range	
Rasmussen[25]	1923	50	—	—	560	400— 855	unit = weight (mg)
Berblinger[1]	1932	37	964	500—1400	593	300— 900	
Bockelmann[2]	1934	99	1204	640—2420	♂ 421 ♀ 510	160— 840	
Meldolesi-Pansadoro[20]	1937	12	985	411—1314	—	—	
Namiki et al[21]	1938	42	1240	750—1920	—	—	
Ottaviani[24]	1939	70	1230	750—2000	570	300—1300	
Cardillo-Bossi[5]	1941	17	911	270—1216	—	—	
Marx et al[19].	1947	90	950	520—1740	600		S =10.3
Karlas[15]	1948	171	939	455—1750	—	—	
Satoo[28]	1949	♂ 397 ♀ 156	—	—	♂ 750 ♀ 840	—	unit = weight (mg)
Busch[4]	1951	Va 788 Vp 243	890	450—1530	♂ 640 ♀ 660	240—1230	good fit in 70.5% gross difference 5.5%
Hisagane et al[11]	1951	39	910	600—1710	590	320—1080	Vp/Va=64.9(48.8～92.3) r = 0.79
Dill[9]	1952	106	869	521—1780	570	310— 990	Vp/Va =75 (55—85)
Tori[35]	1953	429	763～ 875	400—1500	—	—	
DiChiro-Nelson[8]	1962	Va 48 Vp 51	754	489—1229	608	400— 945	Vp/Va =79 (46— 118) r = 0.854
Seki	1965	Va 70 Vp 12	853	478—1257	655	256— 910	

The evaluation of author's method is shown summarily in Table 1, 2, and 3. This result is satisfactory, particularly for clinical practice, when compared with those of the other's methods.[5][8][20] Apparting from the problem whether there is a constant relationship between Vr and Vp, the sellar volume is able to be estimated from three linear components of the skull roentgenograms with high accuracy.

There have been many studies on the anatomical volume of the sella turcica and the piutitary gland in the literature, though only few are found in Japanese literatures. Some of them are listed in Table 3. One glance over this list would make aware of the large difference among the reported values on the anatomical sellar volume. Karlas[15] has estimated the error to be "a good 10 per cent of the average figures", chiefly because of the difficulty in assigning lateral and superior boundaries. DiChiro and Nelson[8] have, also, stated that the error is probably closer to 20 per cent. The roentgenographic volume may be rather accurate and suitable for some medical investigations than the anatomical volume. It is

necessary to re-examine the relationship between the sellar size, the pituitary volume and the pituitary function, because a majority of these investigations have based on the anatomical sellar volume, or linear components and/or area of the roentgenogram.

The relationship between the pituitary and the sella turcica is one of the great important problems in the volumetric study. There is a certain degree of parallelism between the pituitary and the sella,[3)4)] and the estimation of the sellar volume may be assumed to reflect the volume and perhaps the activity of the pituitary gland, as Silvermann[32)], Kovács and Góth[17)], and others have described. There are, however, some limitations to obtain the pituitary volume from the sellar volume. Although Mahmoud[18)] and DiChiro[7)] has verified that the length and depth of the sella turcica correspond with those of the pituitary gland, many authors[2)16)24)25)] have been of the opinion that the size of the sella permits only uncertain conclusion as to the pituitary size. Hrdlicka[13)] in 1898 described that the sella turcica is not really a perfect mold of the hypophysis, but the excess is small. Howe[12)] in 1919 stated that the hypophysis fills about the pituitary fossa transversely, but not in antero-posterior direction. According to Rasmussen,[25)26)] "from numerous studies, it is evident that it varies greatly in size and shape in normal individuals. There may be wide variation between the bony compartment and the weight of the inclosed hypophysis." In 1926, Schüller[34)] pointed out that the pituitary gland can be hypertrophied without causing a visible enlargement of the sella. In cases, where the pituitary gland is atrophic, the sella is usually not smaller than normal, because the soft parts lying around the pituitary fill the empty space. Therefore, the pituitary fossa does not correspond exactly to the shape and to the size of the pituitary gland.

In other words, the parallelism is not constant because of various causal factors. Intrasellar contents are not only composed of the pituitary gland, but also its covering, connective tissue, perihypophyseal venous plexus and subarachnoidal cyst, etc. The dura, enclosing the pituitary gland may occupy about 25 per cent of all of the weight of the intrasellar contents.[25)] The subarachnoidal space, also, occupies at times the large volume.[7)10)14)23)] The pituitary can be increase in size mostly at the presence of venous filling as in pregnancy without alterating the bony sella, and the pituitary may even exceed the volume of the sella.[8)]

On the other hand, the pituitary may so far fail to fill the sella, so-called "empty sella".[4)8)] In 788 cases, Busch[4)] found the "empty sella" in 5.5 per cent and noted that the "empty sella" is usually larger than normal. DiChiro and Nelson,[8)] also, reported the similar case. In 66 cases, they found one large but "empty sella".

In addition to these normal anatomical charactors, there are some limits in pathological changes in obtaining the pituitary volume from the sellar volume. The sella may enlarge without enlargement of the pituitary gland. Dilated third ventricle, parasellar tumors, aneurysma, non-specific intracranial high pressure, and tumor of the epipharynx and the sphenoid sinus, etc., may cause sellar enlargement. Therefore, the enlargement of the sella does not mean that of the pituitary. And when the pituitary volume decreases with senile degeneralization, the osseous tissue does not become smaller.

The relationship between the sellar size and the pituitary function is, also, one of the interesting and clinically important problems in the volumetric study. In 1922 Royster and Rodman[27)] described that, "the size of the sella as measured on the flat plate is probably a very inaccurate guide to the function of the pituitary gland. No correlation between the size of a child's fossa and clinical evidence of an over- and under-active gland." It is sure that the volume of the pituitary gland is not necessarily proportionate

to its activity. Morevoer, in the same volumes of the pituitary, their qualitative structures are not uniform. But, there are some workers,[8)17)32)33)] who presented the relationship between the sellar size and the pituitary function.

As mentioned above, there are some limitations in estimating the volume of the pituitary gland from that of the sella, but it is a true fact that the marked discrepancy is the exception rather than the rule as presented in this paper.

The author wishes to re-examine the relationship between the sellar size, the pituitary volume and the pituitary function from the three dimensional view-point; for the usage of the roentgenographic volume of the sella turcica.

Summary

1) The author's method was evaluated by the relationships between Vr, Va and Vp.

2) The relationship between Vr and Va was examined by using 70 cases of the adult dry skulls. Mean Vr=808 cu. mm. Mean Va=853 cu. mm. Mean Discrepancy=8% $r=0.863$ ($p \leqq 0.1$)

3) The relationship between Vr and Vp was examined by using 12 cases of the skulls of the fresh cadavers.

Mean Vr=896 cu. mm. Mean Vp=655 cu. mm. Mean Discrepancy=27% $r=0.818$ ($p \leqq 0.1$)

4) The results were compared with those of the other methods, especially DiChiro's method, and verified the author's method being satisfying and practically available.

5) The relation of the sellar size to the pituitary volume and its function was discussed.

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